IS 10069 (1992): Hydraulic fluid power - Positive displacement pumps, motors and integral transmissions - Determination of steady-state performance [PGD 16: Fluid Power]

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भारतीय मानक

द्रवचालित तरल पावर — घनात्मक विस्थापन पम्प, मोटर और समाकल प्रेषण — स्थिर-दशा कार्यकारिता ज्ञात करना

(पहला पुनरीक्षण)

Indian Standard

HYDRAULIC FLUID POWER — POSITIVE DISPLACEMENT PUMPS, MOTORS AND INTEGRAL TRANSMISSIONS — DETERMINATION OF STEADY-STATE PERFORMANCE

(First Revision)

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October 1992 **Price Group 7**

Hydraulic Fluid Power Systems Sectional Committee, PE 15

NATIONAL FOREWORD

This Indian Standard which is identical with ISO 4409 : 1986 'Hydraulic fluid power — Positive displacement pumps, motors and integral transmissions — Determination of steady — State performance' issued by the International Organization for Standardization (ISO), was adopted by the Bureau of Indian Standards on the recommendations of the Hydraulic Fluid Power Systems Sectional Committee (PE 15) and approval of Production Engineering Division Council.

This standard was first published in 1982. To align it with international practices, ISO 4409 : 1986 has been adopted in this revision. In this revision, methods for determining the performance and efficiency of motors and integral transmissions have been included along with the positive displacement pumps. It further describes requirements for test installations, test procedures (under steady-state conditions) and presentation of test results.

The text of ISO standard has been approved as suitable for publication as Indian Standard without deviation. Certain conventions are however not identical with those used in the Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear, referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker in the International Standard while in Indian Standards the current practice is to use a point (.) as the decimal marker.

In the adopted standard reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated.

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 31	IS 1890 Quantities, units and symbols	Identical
ISO 1219	IS 7513 : 1974 Graphical symbols for fluid power systems	Technically equivalent
ISO 4391	IS 11147 : 1984 Recommendations for parameter definitions and letter symbols for hydraulic fluid power pumps, motors and integral transmissions	Identical
ISO 5598	IS 10416 : 1992 Fluid power systems and components — Vocabulary	—do—
IEC Pub 34-2	IS 4889 : 1968 Methods of determination of efficiency of rotating electrical machines	Technically equivalent
IEC Pub 51	IS 1248 (all parts) Direct acting indicating analogue electrical measuring instruments and their accessories	—do—

In reporting the results of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960, 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

HYDRAULIC FLUID POWER — POSITIVE DISPLACEMENT PUMPS, MOTORS AND INTEGRAL TRANSMISSIONS — DETERMINATION OF STEADY-STATE PERFORMANCE

(First Revision)

0 Introduction

In hydraulic fluid power systems, power is transmitted and controlled through a liquid under pressure within an enclosed circuit. Pumps are components which convert rotary mechanical power into hydraulic fluid power. Motors are components which convert hydraulic fluid power into rotary mechanical power. Integral transmissions (hydraulic drive units) are a combination of one or more hydraulic pumps and motors and appropriate controls forming a component.

With very few exceptions, all hydraulic fluid power pumps and motors are of the positive displacement type, i.e. they have internal sealing means which make them capable of maintaining a relatively constant ratio between rotational speed and fluid flow over wide pressure ranges. They generally use gears, vanes or pistons. Non-positive displacement components, such as centrifugal or turbine types, are seldom associated with hydraulic fluid power systems.

Pumps and motors are available either as "fixed" or "variable" displacement types. Fixed displacement units have preselected internal geometries which maintain a relatively constant volume of liquid passing through the component per revolution of the component's shaft. Variable displacement components have means for changing the internal geometries so that the volume of liquid passing through the component per revolution of the component's shaft can be changed.

This International Standard is intended to unify testing methods for hydraulic fluid power positive displacement hydraulic pumps, motors and integral transmissions to enable the performance of different components to be compared.

1 Scope and field of application

This International Standard specifies methods for determining the performance and efficiency of hydraulic fluid power positive displacement pumps, motors and integral transmissions. It applies to components having continuously rotating shafts.

This International Standard describes requirements for test installations, test procedures (under steady-state conditions) and the presentation of test results.

Annex A gives guidance as to the use of practical units for the expression of results.

Annex B contains information on errors and classes of measurement accuracy. The measurement accuracy is divided into three classes: A, B and C.

Annex C provides a pre-test checklist of those items on which agreement is recommended between the parties concerned.

2 References

ISO 1219, *Fluid power systems and components — Graphic symbols.*

ISO 4391, *Hydraulic fluid power — Pumps, motors and integral transmissions — Parameter definitions and letter symbols.*

ISO 5598, *Fluid power systems and components — Vocabulary.*

IEC Publication 34-2, *Rotating electrical machines — Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles).*

IEC Publication 51, *Recommendation for direct acting indicating electrical measuring instruments and their accessories.*

3 Definitions

The definitions of quantities and units, and the letters used as symbols are given in ISO 31 and ISO 4391.

For the purposes of this International Standard the following definitions of concepts together with their respective symbols (except for concepts in general use defined in ISO 5598) are applicable.

NOTE — When there is no risk of ambiguity (i.e. when a test has been carried out on a pump or a motor), the superscripts "P", "M" and "T" specifying that the quantity concerns, respectively, a pump, a motor or an integral transmission, can be omitted.

3.1 Volume flow rate

3.1.1 volume flow rate, q_V: The measured flow volume per unit of time.

3.1.2 drainage flow rate, q_{V_d}: The volume rate of flow from the casing of a component.

3.1.3 effective outlet flow rate of a pump, $q^P_{V_{2,e}}$: The actual flow rate measured at the pump outlet at the temperature $\theta_{2,e}$ and pressure $p_{2,e}$ at the outlet of the pump. If the flow rate is measured downstream of the pump at temperature θ and pressure p, that flow rate is corrected to give the effective outlet value as follows:

$$q^P_{V_{2,e}} = q_V \left[1 - \left(\frac{p_{2,e}-p}{\overline{K}_\tau}\right) + \alpha\,(\theta_{2,e}-\theta)\right]$$

3.1.4 effective inlet flow rate on a motor, $q^M_{V_{1,e}}$: The actual flow rate measured at the motor inlet at the temperature $\theta_{1,e}$ and pressure $p_{1,e}$ at the inlet to the motor. If the flow rate is measured downstream of the motor outlet at temperature θ and pressure p, that flow rate is corrected to give the effective inlet value as follows:

$$q^M_{V_{1,e}} = q_V \left[1 - \left(\frac{p_{1,e}-p}{\overline{K}_\tau}\right) + \alpha\,(\theta_{1,e}-\theta)\right]$$

If the motor has an external drainage, the drainage flow rate $q^M_{V_d}$ shall be corrected to refer to the inlet condition used for computing $q^M_{V_{1,e}}$ as follows:

$$q^M_{V_{1,e}} = q_V \left[1 - \left(\frac{p_{1,e}-p}{\overline{K}_\tau}\right) + \alpha\,(\theta_{1,e}-\theta)\right] + q_{V_d} \left[1 - \left(\frac{p_{1,e}-p_d}{\overline{K}_\tau}\right) + \alpha\,(\theta_{1,e}-\theta_d)\right]$$

3.2 rotational frequency (shaft speed), n: The number of revolutions of the drive shaft per unit of time. The direction of rotation (clockwise or counter-clockwise) is specified from the point of view of the observer looking at the end of the shaft. It may also be defined by diagram, if necessary.

3.3 torque, T: The measured value of the torque in the shaft of the test component.

3.4 Pressure

3.4.1 effective pressure, p_e: The fluid pressure, relative to atmospheric pressure, having a value which is

- positive, if this pressure is greater than the atmospheric pressure; or

- negative, if this pressure is less than the atmospheric pressure.

3.4.2 drainage pressure, p_d: The pressure, relative to atmospheric pressure, measured at the outlet of a drainage connection on a component casing.

3.5 Power

3.5.1 mechanical power, P_m: The product of the torque and rotational frequency measured at the shaft of a pump or motor.

$$P_m = 2\pi\, nT$$

3.5.2 hydraulic power, P_h: The product of the flow rate and pressure at any point.

$$P_h = q_V \cdot p$$

3.5.3 effective outlet hydraulic power of a pump, $P^P_{2,h}$: The total outlet hydraulic power of a pump.

$$P^P_{2,h} = q_{V_{2,e}} \cdot p_{2,e}$$

3.5.4 effective inlet hydraulic power of a motor, $P^M_{1,h}$: The total inlet hydraulic power of a motor.

$$P^M_{1,h} = q_{V_{1,e}} \cdot p_{1,e}$$

NOTE — The total energy of a hydraulic fluid is the sum of the various energies contained in the fluid. In 3.5.3 and 3.5.4, the kinetic, positional and strain energies of the fluid are ignored and the power is calculated using the static pressure only. Should these other energies have a significant effect on the test results, due account should be taken of them.

3.6 Efficiency

3.6.1 pump overall efficiency, η^P_t: The ratio of the power transferred to the liquid, at its passage through the pump, to the mechanical input power.

$$\eta^P_t = \frac{(q_{V_{2,e}} \cdot p_{2,e}) - (q_{V_{1,e}} \cdot p_{1,e})}{2\pi\, nT}$$

3.6.2 motor overall efficiency, η^M_t: The ratio of the mechanical output power to the power transferred from the liquid at its passage through the motor.

$$\eta^M_t = \frac{2\pi\, nT}{(q_{V_{1,e}} \cdot p_{1,e}) - (q_{V_{2,e}} \cdot p_{2,e})}$$

3.6.3 integral transmission overall efficiency, η^T_t: The ratio of the output mechanical power to the input mechanical power.

$$\eta^T_t = \frac{n_2 \cdot T_2}{n_1 \cdot T_1}$$

4 Symbols and units

4.1 The symbols and units used throughout this International Standard are as shown in table 1.

4.2 The letters and figures used as subscripts to the symbols listed in table 1 are as specified in ISO 4391.

4.3 The graphical symbols used in figures 1, 2 and 3 are in accordance with ISO 1219.

5 Test installations

5.1 Pump test circuits[1)]

5.1.1 An open test circuit suitable for testing pumps as shown in figure 1 shall be used.

5.1.1.1 Where a pressurized inlet condition is required, a suitable means shall be provided to maintain the inlet pressure within the specified limits (see 6.2.1).

5.1.2 A closed test circuit, alternative to figure 1, is shown in figure 2. In this circuit the boost pump provides a flow slightly in excess of the total circuit losses; a greater flow may be provided for cooling purposes.

5.2 Motor test circuit[1)]

A test circuit suitable for testing motors using a controlled fluid supply as shown in figure 3 shall be used.

5.3 General requirements

5.3.1 The installation shall be designed to prevent air entrainment and precautions shall be taken to remove all free air from the system before testing.

Table 1 — Symbols and units

Reference clause	Quantity	Symbol	Dimensions[1)]	Unit[2)]
3.1	Volume flow rate[2)]	q_V	$L^3 T^{-1}$	m^3/s
3.2	Rotational frequency	n	T^{-1}	s^{-1}
3.3	Torque	T	$ML^2 T^{-2}$	N·m
3.4	Pressure	p	$ML^{-1} T^{-2}$	Pa[3)]
3.5	Power	P	$ML^2 T^{-3}$	W
	Mass density	ϱ	ML^{-3}	kg/m^3
	Isothermal bulk modulus secant	$\overline{K}_T$	$ML^{-1} T^{-2}$	Pa
	Kinematic viscosity	ν	$L^2 T^{-1}$	m^2/s
	Temperature	θ	Θ	K
	Coefficient of cubic thermal expansion	α	Θ^{-1}	K^{-1}
3.6	Efficiency	η	Pure number	

1) M = mass; L = length; T = time; Θ = temperature

2) The use of practical units for the presentation of results is described in annex A.

3) 1 Pa = 1 N/m^2

1) Figures 1, 2 and 3 illustrate basic circuits which do not incorporate all the safety devices necessary to protect against damage in the event of any component failure. It is important that those responsible for carrying out the test give due consideration to safeguarding both personnel and equipment.

5.3.2 The component shall be installed and operated in the test circuit in accordance with the manufacturer's operating instructions.

5.3.3 Tests shall normally be carried out in still air; the ambient temperature and any variation from still air conditions shall be recorded.

5.4 Filtration

5.4.1 A filter shall be installed which provides a standard of filtration approved by the pump or motor manufacturer.

5.4.2 The position, number and specific description of each filter used in the test circuit shall be stated.

5.5 Positioning of tapping points

5.5.1 Where pressure measurements are made within a pipe, the pressure-tapping point shall be positioned not less than twice and not more than four times the pipe diameter from the component port face.

NOTE — Greater distances may be used provided consideration is given to the effect of pipe losses.

5.5.2 Where temperature measurements are made within a pipe, the temperature-tapping point shall be positioned between two and four times the pipe diameter from the pressure-tapping point further away from the component.

6 Test procedures

6.1 General tests

6.1.1 Pre-test condition

Before the tests are carried out, the component shall be "run in" in accordance with the manufacturer's recommendations.

6.1.2 Test fluids

6.1.2.1 Since the performance of a component may vary considerably with the viscosity on the fluid, a stated fluid approved by the manufacturer of the component when carrying out the tests shall be used. Information concerning the fluid shall be recorded.

6.1.2.2 The kinematic viscosity, ν, and the mass density of the fluid, ϱ, at the controlled temperature used during the test shall be stated.

6.1.2.3 The values used for the isothermal secant bulk modulus, $\overline{K}_T$, and for the coefficient of cubic thermal expansion, α, shall be stated.

6.1.3 Temperatures

6.1.3.1 Controlled temperature

The tests shall be carried out at a stated fluid temperature measured at the inlet to a pump or motor within the range recommended by the component manufacturer, the indicated temperature being maintained within the limits stated in table 2.

Table 2 — Permissible variation in indicated fluid temperature

Class of measurement accuracy (see annex B)	A	B	C
Variation of temperature indication, K	± 1,0	± 2,0	± 4,0

6.1.3.2 Other temperatures

The following temperature measurements shall be recorded:

a) the temperature at the outlet of a pump or motor;

b) the temperature at the point of measurement of flow;

c) the drainage fluid temperature (if applicable);

d) the ambient temperature.

NOTE — For an integral transmission, it may not be possible to measure some of the above. Note this on the test report.

6.1.4 Atmospheric pressure

The absolute ambient atmospheric pressure during the test shall be recorded, if it is significant to the test.

6.1.5 Casing pressure

If the fluid pressure within the casing of a component may affect its performance, its value shall be recorded during the tests.

6.1.6 Steady-state conditions

6.1.6.1 When steady-state test conditions are reached for a specific test condition, only one set of readings of individual quantities shall be taken over concurrent common time periods. Each reading shall be recorded as the mean value of each quantity being measured.

6.1.6.2 Each set of readings taken for a controlled value of a selected parameter shall be recorded only where the indicated value of the controlled parameter is within the limits shown in table 3.

6.1.7 Test measurements

The number of sets of readings to be taken and their disposition over the range shall be selected in order to give a representative indication of the performance of the component over the full range of the quantity being varied.

Table 3 — Limits of permissible variation of mean indicated values of selected parameters[1)]

Parameter	Permissible variation for classes of measurement accuracy (see annex B)		
	A	B	C
Rotational frequency, %	±0,5	±1,0	±2,0
Torque, %	±0,5	±1,0	±2,0
Volume flow rate, %	±0,5	±1,5	±2,5
Pressures, where $p <$ 2×10^5 Pa gauge, Pa[2)]	$\pm 1 \times 10^3$	$\pm 3 \times 10^3$	$\pm 5 \times 10^3$
Pressures, where $p >$ 2×10^5 Pa gauge, %	±0,5	±1,5	±2,5

1) The permissible variations listed in this table concern deviation of the indicated instrument reading and do not refer to limits of error of the instrument reading (see annex B).

These variations are used as an indicator of steady state, and are also used where graphical results are presented for a parameter of fixed value. The actual indicated value should be used in any subsequent calculation of power or efficiency.

2) 1 Pa = 1 N/m^2

6.2 Pump tests

6.2.1 Inlet pressure

6.2.1.1 During each test, maintain the inlet pressure constant (see table 3) at a stated value within the permissible range of inlet pressures specified by the manufacturer.

6.2.1.2 Carry out the tests at different inlet pressures, if required.

6.2.2 Test measurements

6.2.2.1 Take measurements of input torque, outlet flow rate, drainage flow rate (where applicable) and fluid temperatures, at a constant rotational frequency (see table 3) and at a number of outlet pressures so as to give a representative indication of the performance of the pump over the full range of outlet pressures.

6.2.2.2 Repeat these measurements at other rotational frequencies, as required, to give a representative indication of the performance of the pump over the full range of rotational frequencies.

6.2.3 Variable capacity

If the pump is of the variable capacity type, carry out complete tests for maximum capacity setting and such other settings, as required, e.g. 75, 50 and 25 %.

Each of these settings shall give the required percentage of the flow rate at the minimum outlet pressure at the minimum rotational frequency specified for the test.

6.2.4 Reverse flow

If the direction of flow for the pump can be reversed by means of a capacity control, carry out tests for both directions of flow, if required.

6.2.5 Non-integral boost pumps

If the test pump is associated with a boost and the power inputs can be measured separately, the pumps shall be tested independently and the results presented independently for each pump.

6.2.6 Full-flow integral boost pump

6.2.6.1 If the boost pump is integral with the main pump, which results in the power inputs being inseparable, and the boost pump delivers the full flow of the main pump, the two pumps shall be treated as one integral unit and the results presented accordingly.

NOTE — The inlet pressure measured is the inlet pressure to the boost pump.

6.2.6.2 Any excess flow from the boost pump shall be measured and recorded.

6.2.7 Secondary-flow integral boost pump

If the boost pump is integral with the main pump, which results in the power inputs being inseparable, but the boost pump supplies only a secondary flow to the hydraulic circuit of the main pump and the remainder is by-passed or used for some auxiliary service, such as cooling circulation, then, where practicable, the flows from the boost pump shall be measured and recorded.

6.2.8 Direct coupled pump (Class C only)

6.2.8.1 If a pump is directly coupled to an electric motor having a single rotational frequency the characteristic of which varies with load, it is permissible to derive the input mechanical power from the electrical power input. This is applicable when the rotational frequency variation between "no load" and "full load" is not more than 5 %. The measured flow at measured rotational frequency is corrected to give the calculated flow at "no-load" rotational frequency.

For this purpose, it shall be assumed that the flow/rotational frequency characteristic of the pump is linear and that the torque constant is within the range of correction at any one output pressure.

6.2.8.2 If the electrical power input to an electric motor coupled directly to the pump is used as a means of determining the pump power input, the following conditions shall be complied with:

a) the motor shall only be operated at conditions where the efficiency is known with sufficient accuracy;

b) the motor efficiency shall be determined in accordance with the recommendations of IEC Publication 34-2.

6.2.8.3 Measure the electric power input to a.c. driving motors by the two-wattmeter method.

NOTE — This allows the use of two single-element wattmeters, or one double-element wattmeter, or one single-element wattmeter and suitable switches.

6.2.8.4 Measure the electric power input to d.c. driving motors by either a wattmeter, or an amperemeter and a voltmeter.

6.2.8.5 Indicating instruments with the type and grade of accuracy as laid down in IEC Publication 51 shall be used for measuring electric power in accordance with this clause.

6.3 Motor tests

6.3.1 Outlet pressure

Control the outlet pressure from the motor by a pressure control valve so that a stated outlet pressure is maintained throughout the tests within the limits given in table 3. This outlet pressure shall be consistent both with the applications envisaged for the type of motor and the manufacturer's recommendations.

6.3.2 Test measurements

Take measurements of inlet flow rate, drainage flow rate (where applicable), output torque and fluid temperatures, over the full rotational frequency range of the motor and at a number of input pressures so as to give a representative indication of the performance of the motor over the full range of input pressures.

6.3.3 Variable capacity

If the motor is of the variable capacity type, carry out complete tests for minimum and maximum capacity settings and such other settings, as required, e.g. 75, 50 and 25 %.

Obtain the percentage capacity by setting the adjustment to give the required proportional rotational frequency for the same inlet flow rate with zero output torque. The flow rate shall be chosen so that at minimum capacity the motor runs at maximum test rotational frequency.

6.3.4 Reverse rotation

For motors which are required to operate in both directions of rotation, carry out tests for both directions of rotation, if required.

6.4 Integral transmission tests

6.4.1 Test measurements

6.4.1.1 Take measurements of input torque, output torque, output rotational frequency and of fluid pressure and temperature, where appropriate, over a power range as recommended by the manufacturer for a specified input rotational frequency.

6.4.1.2 Take measurements for several input rotational frequencies, as required, kept within the limits specified in table 3.

6.4.2 Boost pumps

6.4.2.1 If boost pumps or other auxiliaries are integral with the transmission pump and driven by the same input shaft, the pumps shall be treated as one integral unit and this information shall be stated in the test results.

6.4.2.2 If boost pumps or other auxiliaries are driven separately, their power requirement shall be excluded from the transmission performance and this information shall be stated in the test results.

6.4.3 Reverse rotation

If the output shaft is required to operate in both directions of rotation, carry out tests for both directions of rotation, if required.

6.5 Expression of results

6.5.1 General

All test measurements and the results of calculations derived from them shall be tabulated by the testing agency and, preferably, also presented graphically, as described in 6.5.2, 6.5.3 and 6.5.4.

6.5.2 Pump tests

6.5.2.1 For a pump tested at one constant rotational frequency, a graph shall be plotted of effective inlet mechanical power, effective outlet flow rate and overall efficiency against effective outlet pressure and the constant test fluid and other parameters shall be stated as indicated in figure 4[1)].

6.5.2.2 For a pump tested at a number of constant rotational frequencies, the graphical results shall be presented as shown in figure 4 or they shall be plotted against the rotational frequency for different pressure values as shown in figure 5[1)].

1) The graphical results shown in figures 4 to 7 are shown for style of presentation only. No specific or related values are intended.

6.5.3 Motor tests

The results of the motor tests shall be plotted to show output torque, effective inlet flow rate and overall efficiency against output rotational frequency for different effective inlet pressures as shown in figure 6[1].

6.5.4 Integral transmission tests

For an integral transmission test, the results shall be presented for constant input rotational frequency as the overall efficiency, for constant input power, plotted against the output rotational frequency, as shown in figure 7[1].

7 Identification statement (Reference to this International Standard)

Use the following statement in test reports, catalogues and sales literature when electing to comply with this International Standard:

"Test for the determination of steady-state performance conforms to ISO 4409, *Hydraulic fluid power — Positive displacement pumps, motors and integral transmissions — Determination of steady-state performance*".

1) The graphical results shown in figures 4 to 7 are shown for style of presentation only. No specific or related values are intended.

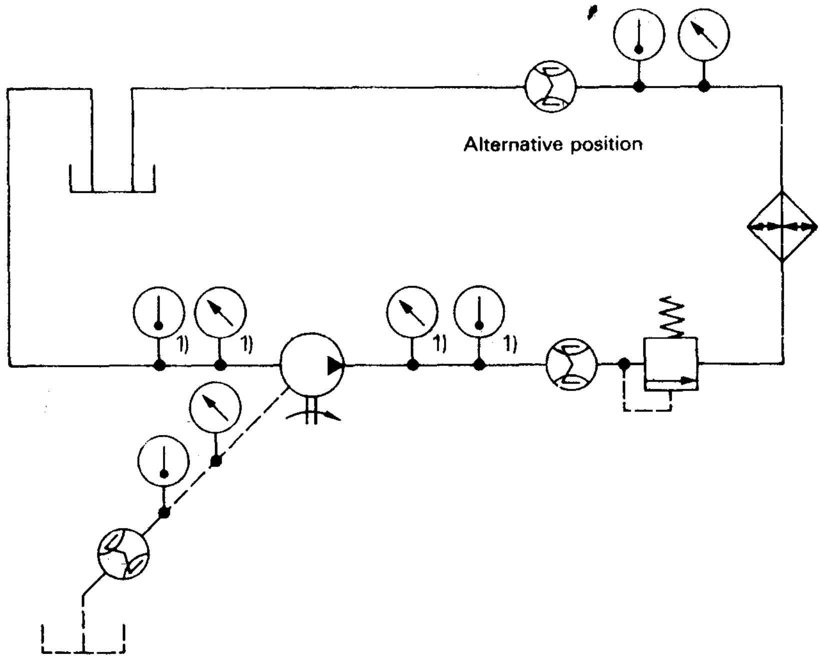

Figure 1 — Test circuit for pump unit (open circuit)

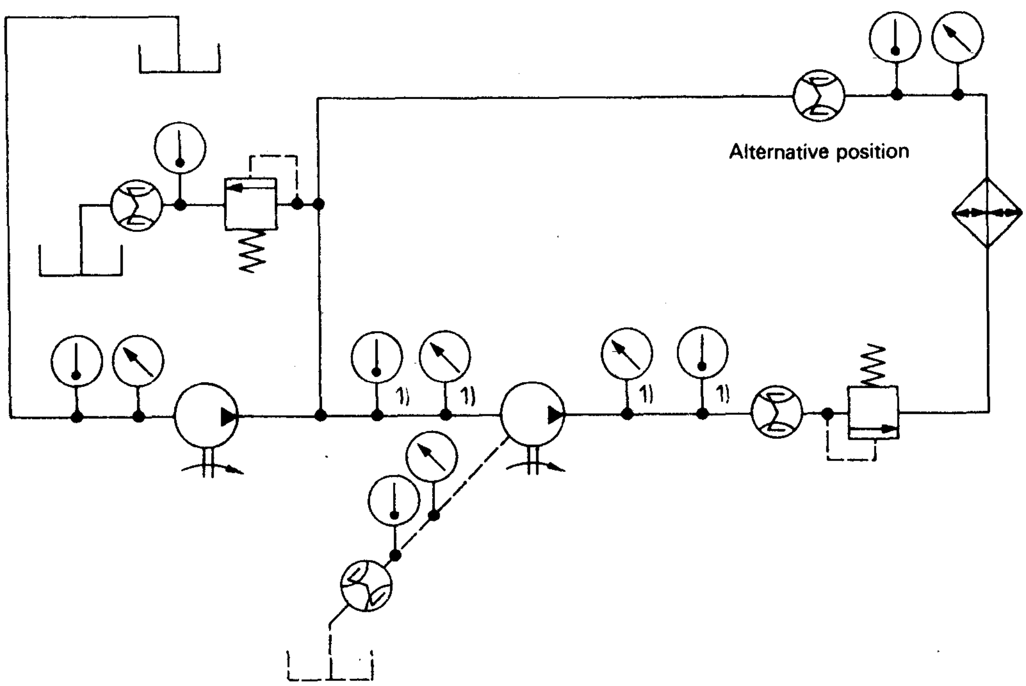

Figure 2 — Test circuit for pump unit (closed circuit)

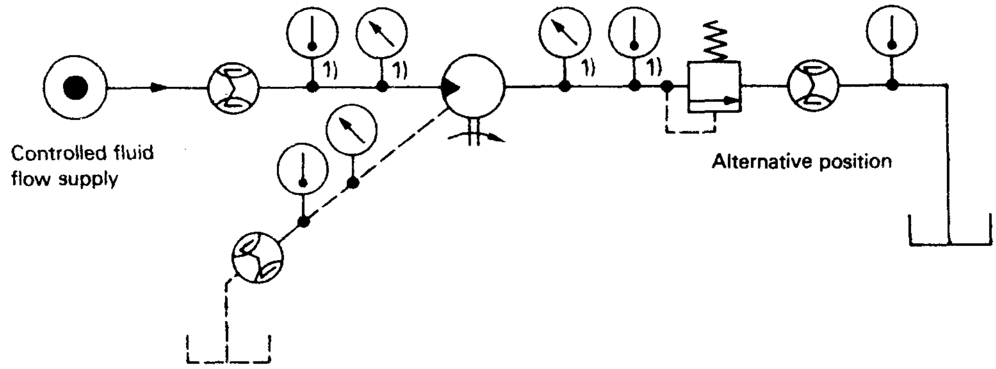

Figure 3 — Test circuit for motor unit

1) For pipe lengths, see 5.5.

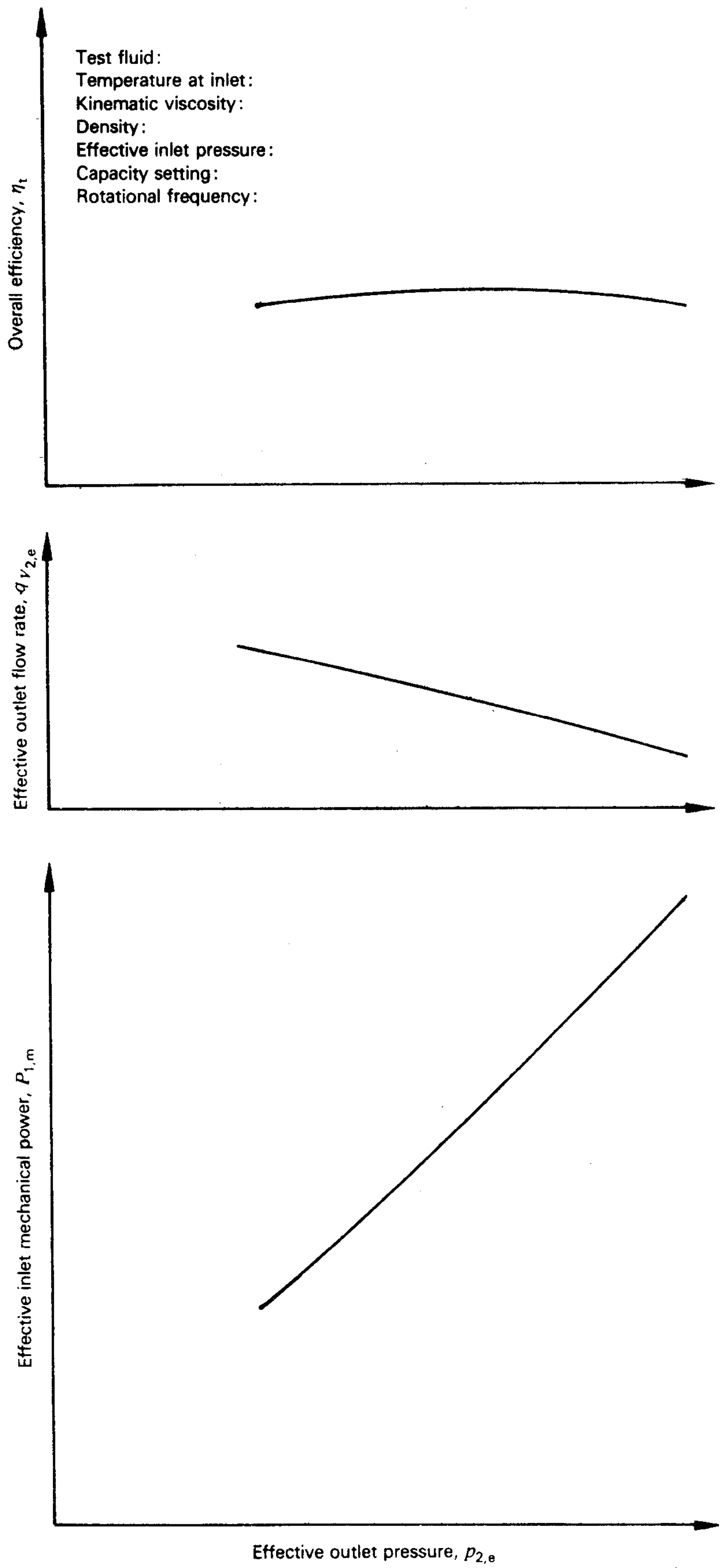

Figure 4 — Graphs of pump performance against effective outlet pressure

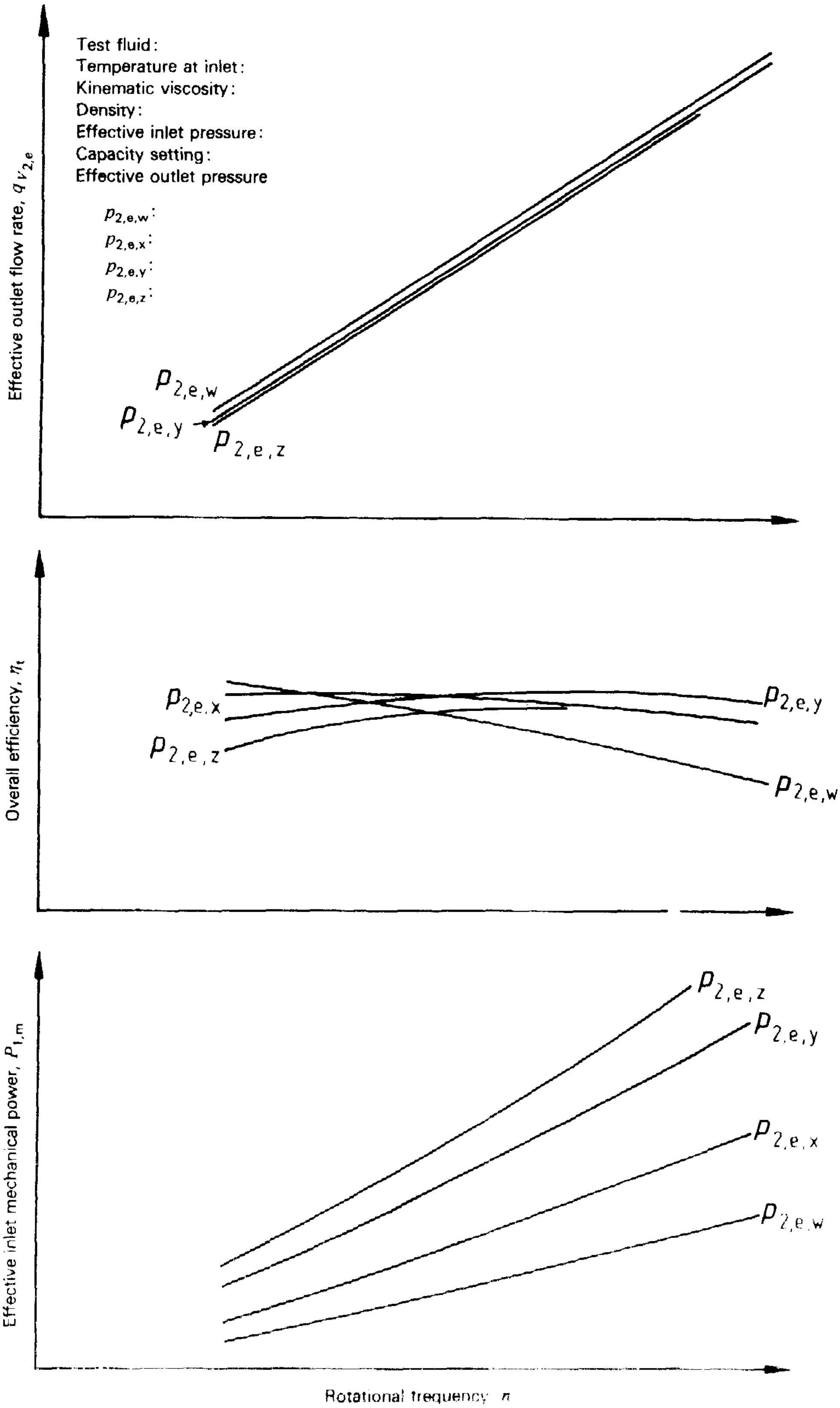

Figure 5 – Graphs of pump performance against rotational frequency

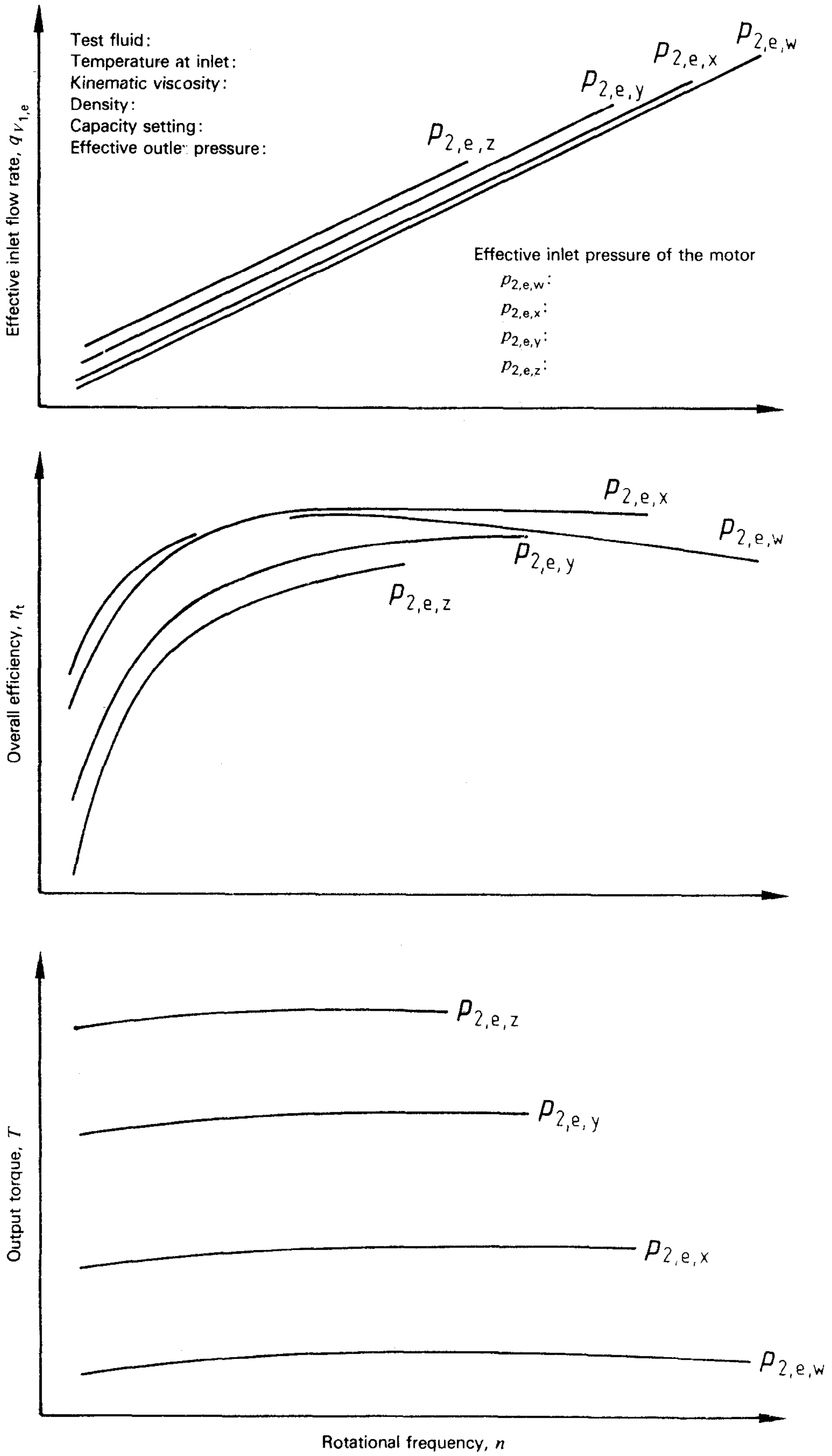

Figure 6 — Graphs of motor performance against rotational frequency

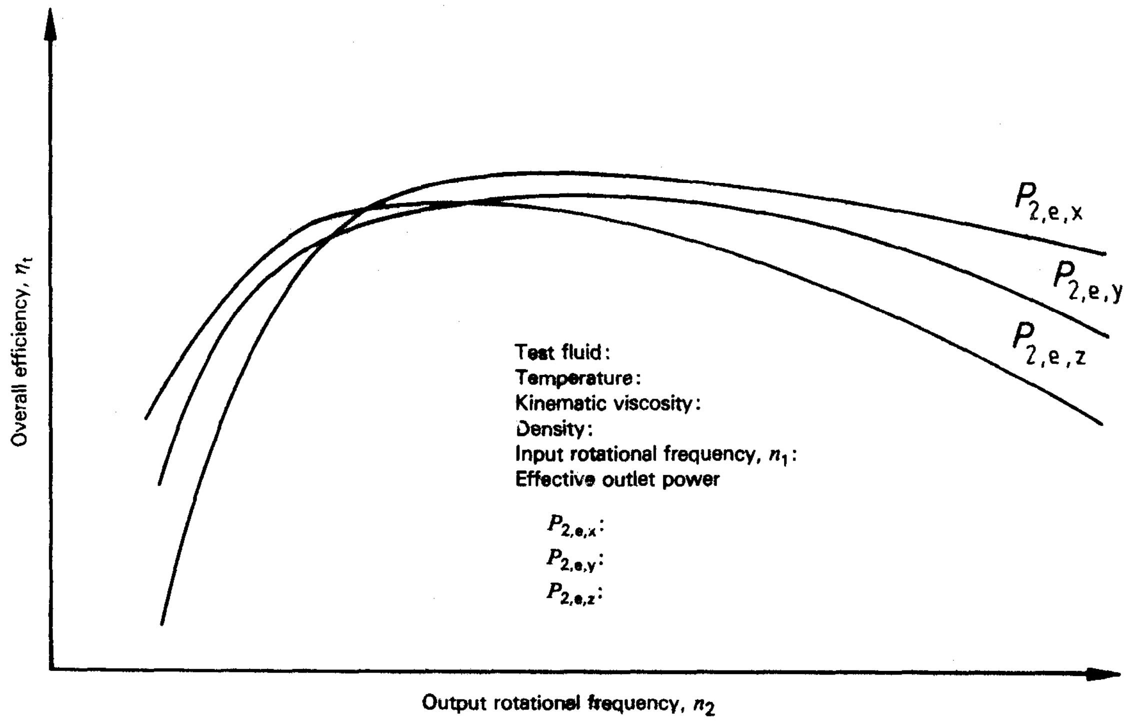

Figure 7 — Integral transmission performance

Annex A

Use of practical units

A.1 Practical units

The results of tests in either tabular or graphical form may be presented using the practical units as given in table 4.

Table 4 — Practical units

Quantity	Symbol	Practical unit
Volume flow rate	q_V	l/min
Rotational frequency	n	min^{-1}
Torque	T	N·m
Pressure	p	bar
Power	P	kW
Mass density	ϱ	kg/l
Isothermal secant bulk modulus	$\overline{K}_T$	bar**
Kinematic viscosity	ν	mm^2/s (cSt)
Temperature	θ	°C
Total efficiency*	η	—

* Efficiency may also be stated as a percentage.

** 1 bar = 10^5 Pa

A.2 Calculation

In order to present results in practical units as given in table 4 the formulae given in this International Standard shall be modified as follows:

A.2.1 Mechanical power (see 3.5.1), in kilowatts

$$P_{\text{m}} = \frac{2\pi\, nT}{60\ 000}$$

A.2.2 Hydraulic power (see 3.5.2, 3.5.3 and 3.5.4), in kilowatts

$$P_{\text{h}} = \frac{q_V \cdot p}{600}$$

$$P^{\text{P}}_{2,\text{h}} = \frac{q_{V_{2,\text{e}}} \cdot p_{2,\text{e}}}{600}$$

$$P^{\text{M}}_{1,\text{h}} = \frac{q_{V_{1,\text{e}}} \cdot p_{1,\text{e}}}{600}$$

A.2.3 Pump overall efficiency (see 3.6.1), as a percentage

$$\eta^{\text{P}}_{\text{t}} = \frac{(q_{V_{2,\text{e}}} \cdot p_{2,\text{e}}) - (q_{V_{1,\text{e}}} \cdot p_{1,\text{e}})}{2\pi\, nT} \times 10^4$$

A.2.4 Motor overall efficiency (see 3.6.2), as a percentage

$$\eta^{\text{M}}_{\text{t}} = \frac{2\pi\, nT}{(q_{V_{1,\text{e}}} \cdot p_{1,\text{e}}) - (q_{V_{2,\text{e}}} \cdot p_{2,\text{e}})}$$

A.2.5 Integral transmission overall efficiency (see 3.6.3), as a percentage

$$\eta^{\text{T}}_{\text{t}} = \frac{n_2 \cdot T_2}{n_1 \cdot T_1} \times 100$$

Annex B

Errors and classes of measurement accuracy

NOTE — The contents of this annex are under review and may be subject to amendment in the future.

B.1 Classes of measurement accuracy

Depending on the accuracy required, the test shall be carried out to one of three classes of measurement accuracy, A, B or C, as agreed between the parties concerned.

NOTES

1 Classes A and B are intended for special cases when there is a need to have the performance more precisely defined.

2 Attention is drawn to the fact that class A and B tests require more accurate apparatus and methods, which increases the cost of such tests.

B.2 Errors

Any device or method shall be used which, by calibration or comparison with International Standards, has been proven to be capable of measuring with systematic errors not exceeding the limits given in table 5.

NOTE — The percentage limits given in table 5 apply to the value of the quantity being measured and not to the maximum values of the test or the maximum reading of the instrument.

B.3 Combination of errors

When calculations of power or efficiency are made, the combination of errors involved in the calculation may be determined by the root mean square method.

Example:

$$\frac{\delta\eta_t}{\eta_t} = \sqrt{\left(\frac{\delta q_V}{q_V}\right)^2 + \left(\frac{\delta p}{p}\right)^2 + \left(\frac{\delta n}{n}\right)^2 + \left(\frac{\delta T}{T}\right)^2}$$

The systematic errors used above, δq_V, δp, δn, and δT, are the systematic errors of instruments and not the maximum values given in table 5. For more precise summation of errors, refer to *Vocabulary of Legal Metrology — Fundamental Terms*, published by the International Organization of Legal Metrology.

Table 5 — Permissible systematic errors of measuring instruments as determined during calibration

Parameter of measuring instrument	Permissible systematic errors for classes of measurement accuracy		
	A	B	C
Rotational frequency, %	± 0,5	± 1,0	± 2,0
Torque, %	± 0,5	± 1,0	± 2,0
Volume flow rate, %	± 0,5	± 1,5	± 2,5
Pressures, where p < 2 bar gauge, bar	± 0,01	± 0,03	± 0,05
Pressures, where $p \geqslant$ 2 bar gauge, %	± 0,5	± 1,5	± 2,5
Temperature, °C	± 0,5	± 1,0	± 2,0
Power (mechanical), % (see 6.2.8.1)		—	± 4,0

Annex C

Pre-test checklist

The following list constitutes a checklist for the selection of appropriate items upon which agreement is recommended between the parties concerned prior to testing[1]:

a) manufacturer's name;

b) manufacturer's identification (type No., serial No.);

c) manufacturer's description of component;

d) direction of rotation of shaft(s) (see 3.2);

e) test circuit (see 5.1 or 5.2);

f) manufacturer's installation requirements (see 5.3.2);

g) filtration equipment used in test (see 5.4);

h) position of pressure tapping points and use of pipe losses in calculation (see 5.5.1);

i) pre-test condition (see 6.1.1);

j) test fluid (by name and description) (see 6.1.2.1);

k) kinematic viscosity of test fluid at test temperature (see 6.1.2.2);

l) mass density of test fluid at test temperature (see 6.1.2.2);

m) isothermal secant bulk modulus of test fluid (see 6.1.2.3);

n) coefficient of cubic thermal expansion of test fluid (see 6.1.2.3);

o) temperature of test fluid during test (see 6.1.3.1);

p) maximum permissible casing pressure (see 6.1.5);

q) inlet pressure for a pump (see 6.2.1);

r) rotational frequencies for test (see 6.2.2, 6.3.2 and 6.4.1);

s) test pressure values (see 6.2.2, 6.3.2 and 6.4.1);

t) percentage capacities for variable displacement (see 6.2.3 and 6.3.3);

u) requirement for reverse flow (see 6.2.4);

v) boost pump information (see 6.2.5, 6.2.6, 6.2.7 and 6.4.2);

w) outlet pressure for a motor (see 6.3.1);

x) requirement for reverse rotation (see 6.3.4 and 6.4.3);

y) expression of results (see 6.5 and annex A);

z) class of measurement accuracy (see annex B).

1) It will not always be necessary to agree upon all these items.

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